Thermal treatment of metallic materials by solar energy:
A strategy for the control of the processing

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Abstract:
The capabilities of solar furnaces as sources of high flux densities are attractive for material processing at high temperatures. The power collected by the solar concentrating devices at CNRS-IMP in Odeillo ranges from a few kilowatts to one megawatt, thus enabling the processing of large surfaces or of great amount of material. The peak flux density ranges between 500 W/cm^2 and 1600 W/cm^2, and temperatures of 3000 K are achieved at the surface of the irradiated materials. In addition, the low cost and the power efficiency of solar concentrating systems make them competitive with conventional processes like lasers or plasma sources.
Recent investigations on the solar hardening and on the induced stresses in solar-irradiated metallic materials have shown encouraging results. Flashes and continuous scanning solar processing have been successfully performed in a small-scale facility of 2 kW, leading to the increase of the hardness and to the introduction of compressive stresses in a thin layer at the surface of XC55 carbon steel.
It was established that the thickness of the modified layer is mainly dependent on the velocity of the scanning or on the duration of the flash.
A design of experiment strategy has been selected and implemented in order to determine the sensitivity of the temperature distributions, gradients and levels versus the operating parameters and the thermal properties of the material. The experiments are performed in a small-scale solar furnace of CNRS-IMP in Odeillo, using two steels as proof materials. Flash irradiation is delivered by a fast mechanical shutter, enabling flashes ranging from 100 ms to a few seconds with satisfying reproducibility. The specimens are disc-shaped, 0.020 m in diameter and 0.012 m in thickness (see fig.1). The sensors are thermocouples installed in the bulk of the specimens. The identification of the influent parameters of the process was achieved through 3D numerical simulations, based on a finite element scheme. The solar

absorption factor appears as the most influent parameter and has to be precisely determined. It is strongly dependent on both temperature and physico-chemical reactions at the surface of the material. A typical situation at the end of the flash (t=1.75s) is illustrated on figures 2 - 4.

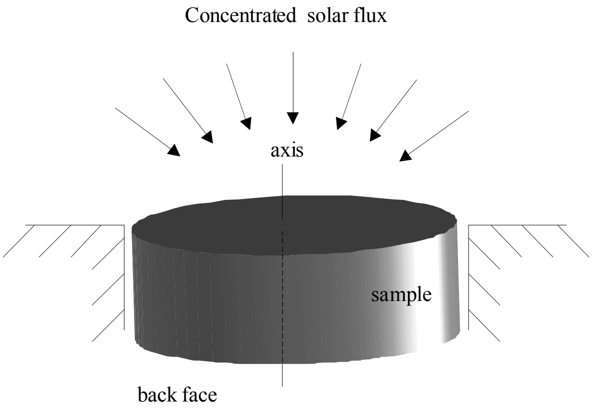

Fig. 1 – Schematic view of specimen

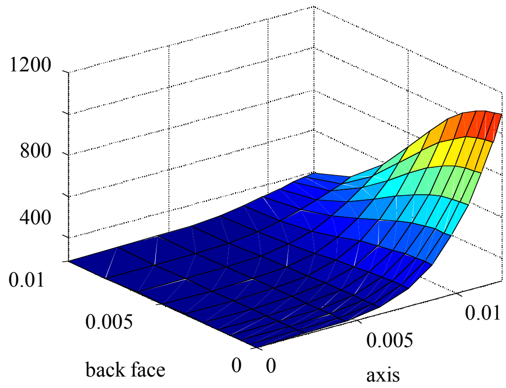

Fig. 2 - Temperature (K)

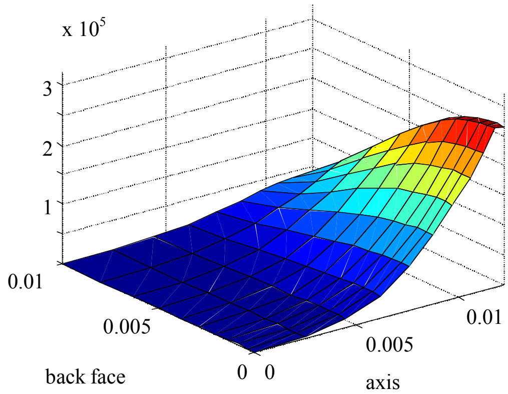

Fig. 3 - Temperature gradients (K/m)

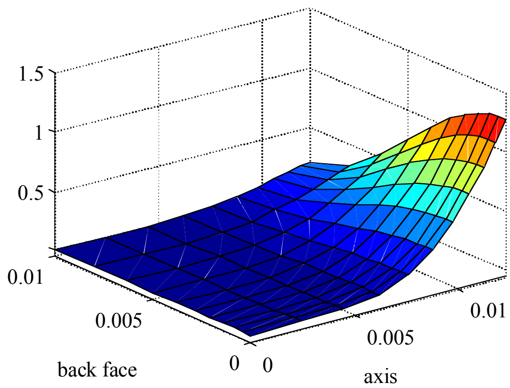

Fig. 4 - Sensitivity of solar absorption factor

The first step of the methodology consists in determining an optimal number of sensors of temperature and in optimizing their positions according to a criteria of sensitivity. The next step is the implementation of an inverse heat transfer method, in order to identify the solar absorption factor during the processing.

The strategy of control of the processing is the last step of the methodology. The objective is to control the operating parameters (duration of irradiation or velocity of scanning), according to the aimed thickness of hardened and compressed layer. This requires a complete modeling of the thermo-mechanical behavior of the material under the action of the concentrated solar radiation. This step is under progress.

This contribution for the control of a simple solar processing of materials shows the capabilities of solar systems regarding some industrial requirements such as the control of the products and the reproducibility of the results.